SILVICULTURAL PRACTICES IN FORESTS OF THE SOUTHERN UNITED STATES: INSECT AND DISEASE CONSIDERATIONS[1]

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Abstract-The relationship between silvicultural practices, e.g. thinning, and pest organisms (insects and diseases) has been investigated extensively in pine species but to a lesser degree in hardwoods. Of critical interest is the potential negative impact to the residual stand resulting from insect damage and diseases that develop as a consequence of silvicultural practices. This is especially true with the increasing economic opportunities in southern forests. Our intent is to report the positive and negative impacts of silvicultural practices for hardwoods in the southern United States that relate to insects and diseases. Emphasis will be placed on stand modification practices. The impact of these practices on current or potential pest problems will be discussed with respect to current and past research concerning insects and disease. Management approaches will be suggested that will help minimize loses from insects and diseases.

INTRODUCTION

The management of forests in the southern United States is Intensifying in some areas as economic opportunities Increase. At the same time, management activities are becoming less intense in other areas as societal values are being considered. There are increasing interests in conservation, wetland preservation, ecosystem preservation, ecosystem management, forest health, and restoration. There is also considerable interest in the sustainability of these forests for purposes of producing fuel, fiber, lumber products, and chemicals. As a result of these latter interests, and in connection with broader ecological interests, the impact from harvesting, periodic flooding (including green tree reservoirs), and fire are of concern (Nebeker and others 1998). In each case, insects and disease-causing organisms have increasingly greater or increasingly fewer opportunities to impact a residual stand as various physiological stresses are added to or removed from the system. Consequently, there is a growing demand to understand these, sometimes complex, relationships.

Our objective is to describe a study the results of which will provide an understanding of the positive and negative aspects of thinning southern bottomland hardwood stands in relation to insect and pathogen populations.

METHODS

Study Area

The study area was located in the Delta National Forest (DNF), Sharkey County, near Rolling Fork, MS during 1997. Campsite 69 served as the principle point of reference within Compartment 38 where treatment areas were established.

Plot design followed the recommendations for standard plots for silvicultural research, set forth by the USDA Forest Service's Northeastern Forest Experiment Station (Marquis and others 1990 • in Meadows and Goelz 1998).

Two 2.4 acre treatment areas were established in Compartment 38. Four measurement plots were set up in each treatment area. Each measurement plot measured 4 x 6 chains. Comers were permanently marked with PVC pipe driven into the ground. Treatments consisted of an unthinned control and a commercial thinning.

Each measurement plot was 0.6 acres, 2 x 3 chains. Each measurement plot was divided into six sectors, each sector was 0.1 acres in size (1 x 1 chain, or 66 x 66 feet). Comers of all sectors and of the measurement plot itself were permanently marked with PVC pipe driven into the ground.

In total there were twenty-four 0.1 acre sector plots utilized in the control group. Likewise, there were twenty-four 0.1 acre sector plots established in the thinned area. All 48 sectors were established and inventoried prior to the commercial thinning.

Pre-thinning inventory determined species composition, initial stand density, insect activity and numbers of diseases, The following variables were measured on all trees greater than, or equal to, 5.5 inches dbh: species, dbh, crown class, tree class, vigor classes, number of epicormic branches, length and grade of sawlogs, and number of insect and disease signs and symptoms. The locations of sample trees within their respective plots were recorded using an x-y coordinate system. An individual number was painted on each tree at about breast height (bh), and a tag was nailed to the base of each tree. A dot was also painted on each tree at bh to assure consistency in measuring dbh. Primary tree species in the area are: sweetgum (*Liquidambar styraciflua*), willow oak (*Quercus phellos*), Nuttall oak (*Q. nuttallii*), sugarberry (*Celtis laevigata*), and various elms (*Ulmus* spp.).

Commonly encountered insect signs and symptoms consisted of: insects themselves in various life stages, frass, bore holes, boring dust, scarring (resulting from callus tissue growing over entrance or exit holes), and galleries. Disease signs and symptoms commonly seen included: slime flux (weeping or oozing indicative of bacterial wetwood), stained wood, fruiting bodies such as conks and mushrooms, cankers, and fungal mats.

Post-thinning inventory was conducted in the same manner as the pre-thinning inventory except that additional data

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were collected concerning thinning related wounding to the canopy, upper-bole (above bh), lower-bole (below bh but above the root collar zone), root collar and roots.

The treated plot was thinned in fall 1997 by professional contractors using chain saws, a mechanical feller, and grapple skidders. The thinned and unthinned plots are surrounded by a 165-acre thinning within two payment units that make up the lower two-thirds of Compartment 36. The thinning was done "from below" to remove poorly formed and otherwise unmerchantable trees and favor well-formed sweetgums and red oaks to improve the quality of the residual stand. Thinning guidelines were developed as prescribed and mandated by the U. S. Forest Service.

Additional insect Sampling

Trapping was conducted, after the thinning had been completed, using both Malaise traps and black light traps. Insect trapping was conducted from 20 August 1997 to 9 October 11997 within Compartment 38. A Townes-style Malaise trap was installed in the control area, with another Townes- style Malaise trap placed in the thinned area. Trapped insects were collected at one or two week intervals in each area. Black light traps were operated one night a week in each treatment area for approximately eight weeks. Trapped insects were stored in 70 percent ethanol. Wood-boring insects from the families Cerambycidae, Scolytidae, and Platypodidae were sorted and removed from the samples and identified to species. All others remain stored in ethanol awaiting further sorting by species of specific interest.

Diversity indices were calculated to characterize the groups of wood-boring insects collected from the unthinned and thinned areas. Indices applied were the Shannon-Weiner index (designated as H'; Magurran, 1988) and evenness index (designated as J'; Pielou, 1966). Statistical differences between the two treatments in terms of the diversity indices were tested following Hutcheson (1970) and procedures from Zar '(1996). Host preferences were determined for the collected wood-boring species according to Yanega (1996), Solomon (1995), and Wood (1982).

RESULTS

Pre-Thinning

The survey of the study area prior to thinning revealed no significant differences in total numbers of trees, insect signs and symptoms, or disease signs and symptoms between the thinned and unthinned areas. A total of 469 trees were inventoried and numbered. Sweetgum, willow oak and Nuttall oak were the primary species in the study area (table 1). Insect signs and symptoms totaled 742 evenly distributed betweenlthe two treatments. Disease signs and symptoms totaled 69 with 59 percent being associated with the trees in the control treatment. The majority of the insect and disease activity was associated with willow and Nuttall oaks (table 1). Of the insect activity, primarily borers, 88 percent of the total occurred on willow and Nuttall oaks.

Post-Thinning

Wounding- Wounding to the residual trees may occur with any entry into a stand. Generally, this occurs when a harvested tree falls into a residual tree, or when logging equipment causes damage to the residual stems. The scraping; and removal of bark exposing xylem is typical of logging damage. A "turn tree", a residual tree around the base of which a log is dragged, is a good example of typical basal wounding. The wounds provide places for insects to enter and serve as infection courts for pathogens.

Table I-Percentages of total numbers of trees, insect borer wounds, anddisease indicators (signs and symptoms) by tree species resulting from the summer 1997 pre-treatment survey of the unthinned plot and tho plot designated to be thinned in Compartment 38 of tho Delta National Forest

Tree species	Percent of total trees	Percent of total borer wounds	Percent of total disease indicators
	Unthinned plot		
Sweetgum	51.4	1.3	24.4
Willow oak	28.2	59.9	46.3
Nuttall oak	9.1	28.3	14.6
Sugarberry	5.4	0	9.8
Other	5.4	10.4	4.9
	Plot designated to be thinned		
Sweetgum	47.4	8.7	10.7
Willow oak	29.4	39.1	71.4
Nuttall oak	6.6	39.4	7.1
Sugarberry	5.4	0	0
Other	11.4	12.8	10.7

There was a great deal of wounding that occurred in Compartment 38 as a result of the thinning operation. In the thinned plots, 84 percent of the residual stems were damaged in some way. Of the total wounds, 53 percent were on the lower-bole (basal wounding), followed by root damage (28 percent), root collar wounding (16 percent), upper-bole wounding (2 percent), and branch wounding or breakage (1 percent). Wounding of the roots, root collar, and lower bole was generally caused by logging equipment or was the result of tree removal (e.g., "turn trees"). Wounding to the upper-boles and branches occurred as cut trees fell into residual trees. During subsequent surveys of these study sites, the wounds will be monitored for additional insect and disease activity.

Insect and Disease Survey

All numbered trees in the thinned and unthinned plots were examined in November 1998 for signs of insects and diseases. One year after the thinning, logging wounds on some trees showed evidence of incipient pathogen activity (table 2), and some had entrance holes caused by wood borers, most notably by ambrosia beetles (Platypus spp.). Eleven nascent infections caused by *Ganoderma lucidum*, *Inonotus* spp., *Schizophyllum commune*, *Stereum gausapatum*, *Stereum hirsutum*, and *Trichaptum biforme* all occurred on one-year-old logging wounds. Two well developed butt rots and a bacterial wetwood infection were in the stand prior to thinning.

Table 2—Comparison of pathogens evident 1 year after thinning in unthinned and thinned stands in Compartment 38 of the Delta National Forest

Disease type and species	Unthinned	Thinned
Canker decay and heartwood decay		
Inonotus hispidus	2	0
Root and butt decay		
Ganoderma lucidum	0	1
Inonotus spp.	0	1
Unidentified pathogen	5	2
Heartwood decay		
Schizophyllum commune	0	2
Stereum gausapatum	0	2
Dead wood decay		
Trichaptum biforme	0	1
Steraum hirsutum	0	4
Wetwood		
Various anaerobic bacteria	4	1
Total number disease types	3.	8
Total number Individuals	11	14

Of the 25 pathogens or disease indicators recorded in unthinned and thinned plots, all but six occurred on willow or Nuttall oaks (table 2). A similar finding was noted in the pre-treatment data (table 1). The ratio of disease indicators per total number of sample trees is 4.6 percent (1 1/239) on the unthinned plot and is 15.7 percent (14/89) on the thinned plot. The new infections accounted for the difference in the number of disease types between the unthinned (3) and thinned (8) plots, as well as the difference in numbers of individual disease indicators between plot types. It is anticipated that these initial decays will be more advanced when examined during the 1999 survey, and that more new infections will have occurred on other logging wounds in the thinned plot.

Of the 434 bore holes caused by insects, 319 were recorded on 87 trees in the unthinned plot and 115 were noted on 27 trees in the thinned plot. Even though the number of total borer holes was less in the thinned plot, the number of borer holes per sample tree increased from 3.7 in the unthinned plot to 4.3 in the thinned plot. This is an indication of the number of new insect borer attacks on logging wounds. Bacterial wetwood in oaks can often be diagnosed because of the slime flux oozing from wood borer attacks. In both plots prior to thinning, oaks had the greatest proportion of borer holes compared to other species (table 1). There were fewer wetwood infections detected in thinned than unthinned plots because roughly one-half of all oaks were removed from the thinned plot. New borer attacks are either not of the type usually associated with wetwood, or have not advanced to the point where the infections begin to ooze out of the holes.

Insect Trapping

A total of 1,371 individuals representing 21 species were collected from the thinned stand and a total of 172 individuals representing 14 species were collected from the unthinned area. Wood-boring insects identified to species belonged to the families Cerambycidae, Scolytidae, and Platypodidae. The majority of cerambycids were taken with Malaise traps, whereas the black light traps captured all scolytids and platypodids. Eight species were trapped in the thinned stand that were not present in the unthinned area, whereas only one species was unique to the unthinned area (table 3). In the thinned stand, five of those eight species were cerambycids.

Table 3—Comparison of wood-boring Insects collected from August to October 1997 in unthinned and thinned stands in Compartment 38 of the Delta National Forest

Family and species	Unthinned	Thinned
Cerambycidae		
Ataxia cyrpta (Say)	0	1
Distenia undata (Fabricius)	1	4
Ecyrus dasycerus (Say)	1	7
Elaphidion mucronatum (Say)	0	6
Enaphalodes atomarius (Say)	0	12
Leptostylus asperatus (Haldeman)	0	8
L. transversus (Gyllenhal)	0	6
Leptura emarginata (Fabricius)	1	0
Neoclytus acuminatus (Fabricius)	12	27
N. mucronatus (Fabricius)	1	28
N. scutellaris (Olivier)	2	22
Styloleptus biustis (LeConte)	1	9
Urographis fasciatus (DeGeer)	2	35
Xylotrechus colonus (Fabricius)	6	55
Scolytidae		
Dryocotes betulae (Hopkins)	11	97
Hylocurus binodatus (Wood)	0	8
Monartum mali (Fitch)	4	34
Xyleborus ferrugineus (Fabricius)	47	353
Xylosandrus crassiusculus (Motschulsky)	21	36
Platypodidae		
Platypus compositus (Say)	60	621
P. flavicornis (Fabricius)	0	1
P. quadridentatus (Olivier)	0	1
Total number species	14	21
Total number individuals	172	1371

In both areas, in terms of numbers of species, most insects taken were cerambycids. However, the most abundant wood-borer collected in the two stands was a platypodid, *Platypus compositus*, which accounted for 35 percent of the total catch in the unthinned area and 45 percent of the total catch in the thinned area. Overall, more species were collected from the thinned stand (table 3).

Even though there were more species of wood borers in the thinned area than in the unthinned area, there was no significant difference in species diversity (H' = 1.99 and 1.83, respectively) between the two areas. Evenness was slightly higher for the unthinned stand (J' = 0.89) than the thinned stand (J' = 0.64), reflecting a more equitable distribution of numbers among collected species (Nebeker and others, in press). This is understandable as nearly half of the insects trapped in the thinned stand were of a single platypodid species, *P. compositus.* As for abundance; much larger numbers of species from all three families were taken in the thinned stand than in the unthinned stand.

All but one of the wood-boring insects collected were species that had host preferences for hardwood tree and shrub species. No one species was collected that was primarly a pest of healthy hardwoods, instead the majority of species were ones that attack weakened, stressed, freshly-felled, or dead and decaying hardwoods. For example, *P. compositus,* the most frequently trapped insect wood-borer, rarely attacks vigorous hardwoods, but instead prefers oak, hickory, maple, and other hardwood species that are severely weakened, are dying, or that have been freshly-felled (Solomon, 1995).

DISCUSSION

The magnitude of logging damage is due to the following principal variables: 1) silvicultural system used, 2) type of equipment and configuration, 3) tree species, 4) spacing (density), 5) size class (age), 6) season of harvest (soil moisture conditions), and 7) operator carelessness (Nebeker and others 1998). The types of damage encountered include limb bteakage and wounding: bole wounding, upper and lower bole; root wounding; and root breakage.

Other reports, most of which were through personal communications, also indicate considerable logging damage as was observed in this study. Meadows (1993) found logging wounds on 62 percent of the residual stems following a thinning operation in a riverfront hardwood stand in Mississippi. The most common types of damage included: 1) branches being broken in the residual canopy; 2) upper and lower bole wounding; and 3) exposure and breakage of roots. Such wounding serves as infection courts for disease organisms and attraction points for various insects that can lead to degrade and potential mortality of the residual stems. In addition, disease propagules such as fungal spores, bacteria, and viruses may be introduced into trees through wounds created by insects, birds, or mammals. The subsequent reduced vigor of individual trees may also reduce the overall health of the residual stand making it susceptible to further attacks by insects and pathogens.

With the results presented above, it is too early to really determine what the impact will be from insects and diseases. Hence it will be necessary to monitor this stand for a number of years to document the changes which take place. This will be the subject of some of our ongoing investigations.

It is our intent to produce a guide similar to one produced by Nebeker and others (1985). They state that although the principal goal of thinning is improving the growth and value of stands, other benefits are obtained, such as hazard reduction for insect infestations, disease epidemics, and damage due to abiotic agents. The mechanics by which thinning reduces these hazards is not completely understood. However, observations indicate that thinning can result in positive and/or negative effects, depending on how, where, when, and why it is conducted. The presence of more than one kind of hazard (e.g., insects and diseases) in a particular area at a given time poses some problems in designing an optimal thinning strategy. Other factors that complicate the situation are the forest type (species composition), stage of stand development, site quality, growth rate, live crown ratio, equipment used, machine operator experience, anticipated direct damage to residual stems, and ultimately the cost effectiveness of the operation. Soil compaction, soil improvement, water quality issues, wildlife habitat enhancement, weed problems, aesthetics, and the like, cannot be ignored if all aspects of thinning are to be taken into account. This is certainly true of the bottomland hardwood landscape.

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